Interpretation of Injection Tests in Fractured Porous Media

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RESEARCH OBJECTIVES

The objective of this study was to quantify wetting front instability in a fracture/matrix system and apply the results to the interpretation of two in-situ injection tests. Understanding fracture flow and wetting front instability is critical for modeling fast pathways, fracture/matrix interaction and contaminant transport in heterogeneous media.

APPROACH

A mathematical representation of a fracture/matrix system was solved by approximate analytical methods and the system stability investigated using a first-order perturbation expansion. Model predictions were compared to field tests in which water was injected into a high permeability fracture and collected in a slot located 1.6 meters below the injection point (Figure 1a). The fraction of injected water recovered in the slot (β) was compared with model predictions to build confidence in the model and to gain insight into the test results.

ACCOMPLISHMENTS

In the first test (Figure 1b) model/data agreement was excellent for early-times (dimensionless times $\tau < 5$, where $\tau = \tau/\tau c$, and τc is the time at which gravitational potential and water potential are equal at the wetting front). Erratic intermediate-time system response was attributed to capillary effects arising from fracture heterogeneity. This behavior resulted in poor model/observation agreement until shortly before test termination, at about $\tau = 18.5$.

A second test (not shown) displayed little influence from fracture heterogeneity, probably because wetting from the first test reduced the effective fracture heterogeneity. The shape of the curves matched closely for all times; however, model predictions overestimated β by a constant factor, consistent with a 20% loss of water from the test bed (or other experimental error).

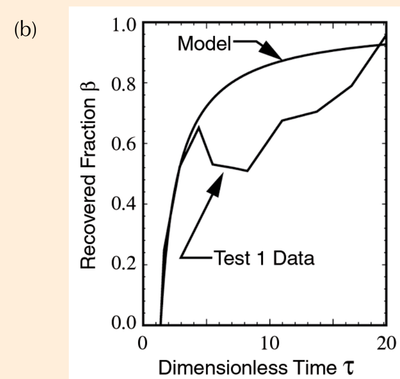

Figure 1. (a) Members of the Ambient Testing Group inserting trays into the collection slot. The trays collected fracture flow from an injection point 1.6 meters above the slot (photo credit: C.M. Oldenburg). (b) The fraction of injected water recovered in the slot (β) vs. dimensionless time τ (Test 1). Model/data agreement is good for early and late times. Poor intermediate-time agreement probably results from fracture heterogeneity.

SIGNIFICANCE OF FINDINGS

The early- and late-time model/data agreement for the first test, and close correspondence in the shape of the recovery curves for the second test, provided confidence that the model accurately portrayed the gross system behavior. Extension of the model to heterogeneous fracture properties may improve model/data agreement. The analysis indicated that the scale of testing was too small to manifest instability, and provided an estimate of the scale needed for future tests.

RELATED PUBLICATIONS

Fairley, J.P., Theoretical and field studies of fracture/matrix interaction, Ph.D. dissertation, Department of Materials Science and Mineral Engineering, University of California, Berkeley, Calif., 2000.

Wang, J.S.Y. (ed.), Progress report on fracture flow, drift seepage and matrix imbibition tests in the Exploratory Studies Facilities, Lawrence Berkeley National Laboratory, Berkeley, Calif., 1998.

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